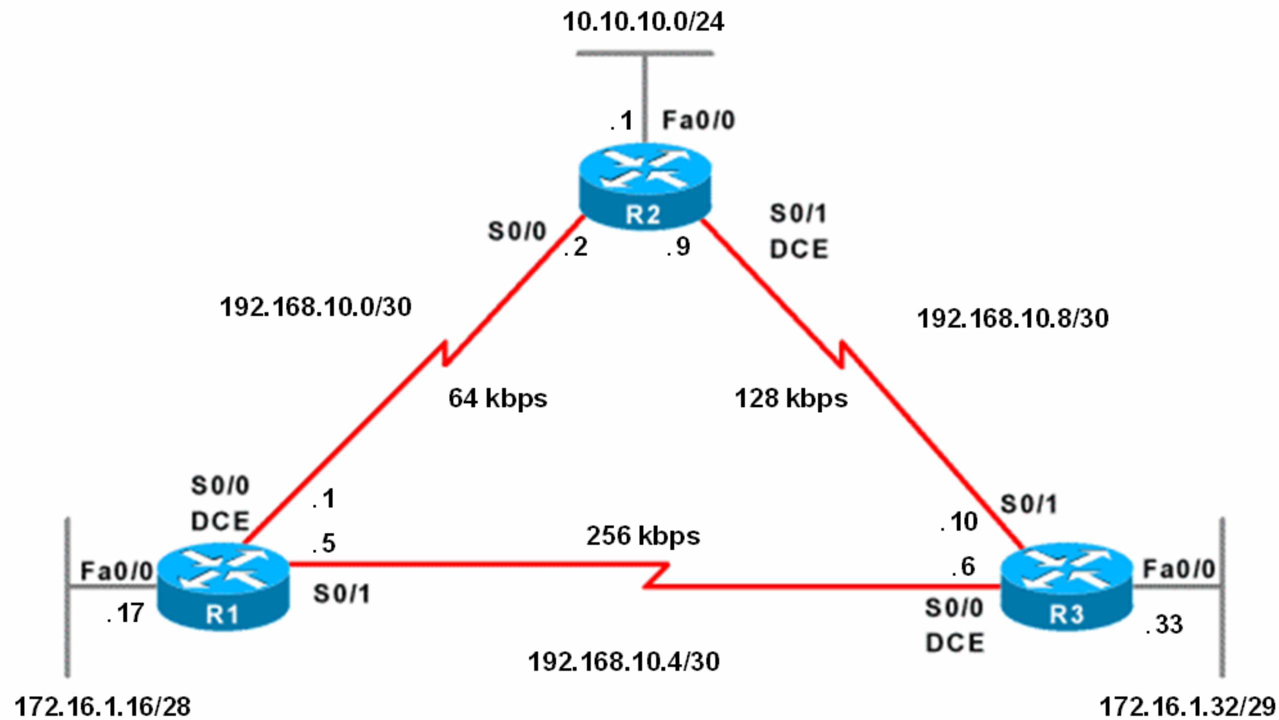
Single Area OSPF Instructional Lab



Lab

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2. Verifying OSPF
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Final Router Configurations

Objective

The objective of this lab is to familiarize the student with the basic configuration and verification of Single Area OSPF. This lab covers the basic commands and outputs associated with Single Area OSPF, except for the DR/BDR election. This will be covered in a separate lab.

Router Pre-Configurations

Router R1

```
version 12.2
!
hostname R1
!
no ip domain-lookup
!
interface FastEthernet0/0
 ip address 172.16.1.17 255.255.255.240
 no shutdown!

interface Serial0/0
 ip address 192.168.10.1
255.255.255.252
 clockrate 64000
 no shutdown
!
interface Serial0/1
 ip address 192.168.10.5
255.255.255.252
 no shutdown
!
line con 0
 exec-timeout 0 0
 logging synchronous
```

Router R2

```
version 12.2
!
hostname R2
!
no ip domain-lookup
!
interface FastEthernet0/0
 ip address 10.10.10.1 255.255.255.0
 no shutdown
!
interface Serial0/0
 ip address 192.168.10.2
255.255.255.252
 no shutdown
!
interface Serial0/1
 ip address 192.168.10.9
255.255.255.252
 clockrate 64000
 no shutdown
!
line con 0
 exec-timeout 0 0
 logging synchronous
```

Router R3

```
version 12.2
!
hostname R3
!
no ip domain-lookup
!
interface FastEthernet0/0
 ip address 172.16.1.33 255.255.255.248
 no shutdown
!
interface Serial0/0
 ip address 192.168.10.6 255.255.255.252
 clockrate 64000
 no shutdown
!
interface Serial0/1
 ip address 192.168.10.10 255.255.255.252
 no shutdown
!
line con 0
 exec-timeout 0 0
 logging synchronous
```

Note: For editing purposes only, subnet masks are sometime shown on a separate line.

Pre-Configuration Notes

Use the Router pre-configurations to configure the three routers.

Router and Interface Types

The routers used in this lab were Cisco 2621s. This means that the interface types are:

FastEthernet 0/0
FastEthernet 0/1 (not used)
Serial 0/0
Serial 0/1

Depending upon the routers you use, your interface types may differ (e.g. FastEthernet 0 and Serial 0). Also, if you are using routers with standard Ethernet interfaces (10Mbps) instead of FastEthernet interfaces (100 Mbps), this may change some of the outputs and routing table metrics shown in this lab.

Keeping output from interrupting keyboard input

The command **`logging synchronous`** configure the console 0 port to keep debug and other output messages from interrupting keyboard input.

```
Router(config)#line console 0
Router(config-line)#logging synchronous
```

Changing the default timeout

By default, after 10 minutes if there is no input via the console, the user will be logged off. Although a good idea in production environment, in a lab environment this can be somewhat annoying. To turn-off the automatic timeout feature, we use the command: **`exec-timeout`** *`minutes`* `[`*`seconds`*`]`, setting both the minutes and seconds to 0.

```
Router(config)#line console 0
Router(config-line)#exec-timeout 0 0
```

Note Concerning FastEthernet Interfaces

This lab was designed using routers with FastEthernet interfaces connected to 10 Mbps Ethernet switches. As a result of the autonegotiation between the router's FastEthernet interface and the 10 Mbps switch port, the router's interface is operating at 10 Mbps. This needs to be taken into account for any routing protocols, such as EIGRP and OSPF that use bandwidth as all or part of the routing metric. The cost associated with this interface will be that of 10 Mbps Ethernet and not 100 Mbps Fast Ethernet.

```
Router#show interface fa 0/0
FastEthernet0/0 is administratively down, line protocol is down
  Hardware is AmdFE, address is 000c.3010.9280 (bia 000c.3010.9280)
  MTU 1500 bytes, BW 10000 Kbit, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
```

The switches in our NetLab configuration have been upgraded to FastEthernet interfaces. This will decrease the routing metric to the LANs by 9.

Note Concerning Serial Interfaces

Most Cisco serial interfaces default to a bandwidth of 1544 Kbps (1.5 Mbps). Some of the routers in our labs have interfaces that have different default values. In order to make this lab consistent with those interfaces that have the 1544 Kbps default, please modify the bandwidth on all serial interfaces as shown below:

```
R1(config)#interface serial 0/0
R1(config-if)#bandwidth 1544
R1(config-if)#exit
R1(config)#interface serial 0/1
R1(config-if)#bandwidth 1544

R2(config)#interface serial 0/0
R2(config-if)#bandwidth 1544
R2(config-if)#exit
R2(config)#interface serial 0/1
R2(config-if)#bandwidth 1544

R3(config)#interface serial 0/0
R3(config-if)#bandwidth 1544
R3(config-if)#exit
R3(config)#interface serial 0/1
R3(config-if)#bandwidth 1544
```

1. Configuring OSPF

Configuring Router IDs

The OSPF Router ID is used to uniquely identify the routers in the OSPF routing domain. The OSPF Router ID can be assigned in one of three ways and with this precedence:

1. IP address configured with the OSPF **`router-id`** command
2. Highest loopback address
3. Highest active IP address (any IP address)

Loopback address has the advantage of never going down, thus diminishing the possibility of having to re-establish adjacencies.

In the absence of the router-id or a loopback interface, the router uses the highest IP address among its active interfaces. This interface does not have to be enabled for OSPF. Because loopback interfaces are immune to physical and data link problems, they should be used to derive the router ID instead of a physical interface address. To avoid conflicts with registered network addresses, use private network ranges for the loopback interfaces. Configure the routers using the following commands:

```
R1(config)#interface loopback 0
R1(config-if)#ip address 10.1.1.1 255.255.255.255

R2(config)#interface loopback 0
R2(config-if)#ip address 10.2.2.2 255.255.255.255

R3(config)#interface loopback 0
R3(config-if)#ip address 10.3.3.3 255.255.255.255
```

Enabling OSPF

Now that loopback interfaces are configured, configure OSPF. The network command is used to enable OSPF on any interfaces that have an IP address that belongs to that network. Here is an example:

```
R1(config)#router ospf 1
R1(config-router)#network 172.16.1.0 0.0.0.15 area 0
```

- An OSPF **process ID** is locally significant. In OSPF, the process-ID does not need to match neighboring routers, (unlike IGRP and EIGRP). The ID is needed to identify a unique instance of an OSPF database, because multiple processes can run concurrently on a single router.
- The **wildcard mask** is the inverse of the subnet mask.
- The **area** must be the same on all routers. When configuring a single area, it is good practice to use area 0.

Use the following commands to enable OSPF on each router:

```
R1(config)#router ospf 1
R1(config-router)#network 172.16.1.16 0.0.0.15 area 0
R1(config-router)#network 192.168.10.0 0.0.0.3 area 0
R1(config-router)#network 192.168.10.4 0.0.0.3 area 0


R2(config)#router ospf 1
R2(config-router)#network 10.10.10.0 0.0.0.255 area 0
R2(config-router)#network 192.168.10.0 0.0.0.3 area 0
R2(config-router)#network 192.168.10.8 0.0.0.3 area 0
```

```
R3(config)#router ospf 1
R3(config-router)#network 172.16.1.32 0.0.0.7 area 0
R3(config-router)#network 192.168.10.4 0.0.0.3 area 0
R3(config-router)#network 192.168.10.8 0.0.0.3 area 0
```

2. Verifying OSPF

show ip route

All non-directly connected networks should be visible in the routing table by means of OSPF. We will examine the routing table more closely later in this lab.

```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       <text omitted>

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0
C       192.168.10.4 is directly connected, Serial0/1
O       192.168.10.8 [110/128] via 192.168.10.2, 00:11:32, Serial0/0
                     [110/128] via 192.168.10.6, 00:11:32, Serial0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/74] via 192.168.10.6, 00:11:33, Serial0/1
C       172.16.1.16/28 is directly connected, FastEthernet0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O       10.10.10.0/24 [110/74] via 192.168.10.2, 00:11:34, Serial0/0
C       10.1.1.1/32 is directly connected, Loopback0
R1#

R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       <text omitted>

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0
O       192.168.10.4 [110/128] via 192.168.10.1, 00:19:24, Serial0/0
                     [110/128] via 192.168.10.10, 00:19:24, Serial0/1
C       192.168.10.8 is directly connected, Serial0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/74] via 192.168.10.10, 00:19:24, Serial0/1
O       172.16.1.16/28 [110/74] via 192.168.10.1, 00:19:24, Serial0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.2.2.2/32 is directly connected, Loopback0
C       10.10.10.0/24 is directly connected, FastEthernet0/0
R2#
```

```
R3#show ip route
       <text omitted>

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
O       192.168.10.0 [110/128] via 192.168.10.5, 00:19:44, Serial0/0
                     [110/128] via 192.168.10.9, 00:19:44, Serial0/1
C       192.168.10.4 is directly connected, Serial0/0
C       192.168.10.8 is directly connected, Serial0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.1.32/29 is directly connected, FastEthernet0/0
O       172.16.1.16/28 [110/74] via 192.168.10.5, 00:19:44, Serial0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.3.3.3/32 is directly connected, Loopback0
O       10.10.10.0/24 [110/74] via 192.168.10.9, 00:19:45, Serial0/1
R3#
```

After OSPF routing is enabled on each of the three routers, verify its operation using other show commands. Several important show commands can be used to gather OSPF information.

show ip protocols

This command can be used to verify several items, including:

- That OSPF is enabled and its process ID.
- The OSPF Router ID.
- The networks this router is routing (the interfaces on this router which are enabled for OSPF).
- The Administrative Distance for OSPF is 110.

```
R1#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    172.16.1.16 0.0.0.15 area 0
    192.168.10.0 0.0.0.3 area 0
    192.168.10.4 0.0.0.3 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.2.2.2             110      00:26:07
    10.3.3.3             110      00:26:07
    10.1.1.1             110      00:26:07
  Distance: (default is 110)
```

Repeat the **`show ip protocols`** command for routers R2 and R3 and view the output.

Question 1: What are the Router IDs for each router?

R1: **10.1.1.1** R2: **10.2.2.2** R3: **10.3.3.3**

Question 2: How was the Router ID determined by OSPF? (Which command did you use to configure the OSPF Router ID?)

The OSPF Router ID was configured, determined by the highest loopback interface on each router.

show ip ospf

The show ip ospf command includes the following information:

- That OSPF is enabled and its process ID.
- The OSPF Router ID.
- SPF schedule delay and hold time.
- OSPF area(s).
- Authentication
- Number of times the SPF algorithm has been executed since OSPF was enabled.

```
R1#show ip ospf
 Routing Process "ospf 1" with ID 10.1.1.1
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 External flood list length 0
    Area BACKBONE(0)
        Number of interfaces in this area is 3
        Area has no authentication
        SPF algorithm executed 9 times
        Area ranges are
        Number of LSA 3. Checksum Sum 0x017332
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
```

SPF schedule delay and hold time

```
SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
```

The **show ip ospf** output displays SPF algorithm information. Any time a router receives new information about the topology (addition, deletion, or modification of a link) the router must rerun the SPF algorithm, create a new SPF tree, and update the routing table. The SPF algorithm is CPU intensive and takes a certain amount of time depending upon the size of the area including the number of routers and the size of the link state database. A flapping link can cause an OSPF router to constantly be rerunning the SPF algorithm and thus never properly converging. To minimize this problem, the router waits 5 seconds after receiving an LSU (Link State Update) before running the SPF algorithm, in case there are more LSUs coming. So the router is not constantly running the SPF algorithm there is a Hold Time of 10 seconds, which means the router will wait 10 seconds after running the SPF algorithm before rerunning it again.

Both values for SPF Schedule Delay and Hold Time can be modified.

Repeat the **show ip ospf** command for routers R2 and R3 and view the output.

Question 3: Area 0 is known as what type of area?

Area 0 is known as the Backbone Area.

show ip ospf neighbor

The **`show ip ospf neighbor`** command can be used to verify and help troubleshoot OSPF neighbor relationships. This command should show the Router ID (Neighbor ID) of each neighboring router with State displaying “Full”. Full State means that the router and its neighbor have identical OSPF link state databases.

When troubleshooting OSPF networks, the show ip ospf neighbor command can be used to verify that the router has formed an adjacency with its neighboring routers. If the Router ID of the neighboring router is not displayed or it does not show as a State of Full, the two routers have not formed an OSPF adjacency. The problem may be:

- Incorrect subnet mask causing routers to be on different networks.
- Hello or Dead Timers do not match

Note: On multi-access networks such as Ethernet, the state may show something other than **`FULL`**.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:30    192.168.10.6    Serial0/1
10.2.2.2          1   FULL/  -        00:00:36    192.168.10.2    Serial0/0
R1#
```

Repeat the **`show ip neighbor`** command for routers R2 and R3 and view the output.

Question 4: What does the “Interface” information in the show ip ospf neighbor output represent?

The interface on this router that is forming the neighbor relationship.

Question 5: What does the “Address” information in the show ip ospf neighbor output represent?

This is the IP Address of the neighboring router’s interface.

show ip ospf interface

The show ip ospf interface command displays interface specific OSPF information.

This information includes:

- Interface
- IP address, subnet mask and OSPF Area associated with the interface
- OSPF Process ID associated with this interface
- OSPF Router ID, Network Type, and OSPF Cost of this interface
- Hello timer and Dead timer values
- Number of adjacent neighbors on this interface.
- IP addresses of remote routers that this router has formed an adjacency with on this interface.

```
R1#show ip ospf interface
Serial0/1 is up, line protocol is up
  Internet Address 192.168.10.5/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:03
  Index 3/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.3.3.3
  Suppress hello for 0 neighbor(s)
Serial0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.2.2.2
  Suppress hello for 0 neighbor(s)
FastEthernet0/0 is up, line protocol is up
  Internet Address 172.16.1.17/28, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.1.1.1, Interface address 172.16.1.17
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:04
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 0
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
```

Repeat the **`show ip ospf interface`** command for routers R2 and R3 and view the output.

OSPF Hello Sub-protocol

```
R1#show ip ospf interface
<Output Omitted>
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
```

OSPF routers send **Hellos** on OSPF enabled interfaces. The default is every 10 seconds on multi-access and point-to-point segments and every 30 seconds on NBMA segments (Frame Relay, X.25, ATM)
In most cases OSPF Hello packets are sent as multicast to ALLSPFRouters (224.0.0.5).

The **Dead** interval is the period in seconds that the router will wait to hear a Hello from a neighbor before declaring the neighbor down. Cisco uses a default of four-times the Hello Interval (4 x 10 sec. = 40 seconds, 120 seconds for NBMA).

Both these timers can be modified by using the interface commands:

```
ip ospf hello-interval seconds
ip ospf dead-interval seconds
```

Note: For routers to become adjacent the Hello and Dead timers, along with the network types must be identical between neighbor routers or the Hello packets get dropped and an adjacency will not be formed.

3. Modifying OSPF Timers

Use the **show ip ospf neighbor** command on R1 to view its neighboring routers.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:30    192.168.10.6    Serial0/1
10.2.2.2          1   FULL/  -        00:00:36    192.168.10.2    Serial0/0
R1#
```

The OSPF timers can be adjusted so that routers will detect network failures in less time. This will increase traffic, but this is less of a concern on the high speed core Ethernet segment than on a busy WAN link. Many times there is a need for quick convergence that outweighs the extra traffic. Manually change the Hello and Dead intervals on R1 as follows:

```
R1(config)#interface serial 0/0
R1(config-if)#ip ospf hello-interval 5
R1(config-if)#ip ospf dead-interval 20
```

These commands set the Hello update timer to five (5) seconds and the Dead interval to 20 seconds. Although the Cisco IOS does not require it, configure the Dead interval to four times the Hello interval. This ensures that routers experiencing temporary link problems can recover and are not declared dead unnecessarily, causing a continuance of updates and recalculations throughout the internetwork.

Note: Immediately after changing the Hello interval, Cisco IOS automatically modifies the Dead interval to four times the hello interval. However, do not rely on this feature. Be sure to check to make sure the Dead interval has been changed or modify it manually.

After 40 seconds the Dead Timer will expire. Because R1 and its neighbor R2 have different Hello and Dead timer values, R2 will not accept the Hellos from R1 and the adjacency will no longer exist.

```
05:27:45: %OSPF-5-ADJCHG: Process 1, Nbr 10.2.2.2 on Serial0/0 from FULL to
DOWN, Neighbor Down: Dead timer expired
```

After the Dead timer has expired on R1, issue the **show ip ospf neighbor** command. Notice that the 10.2.2.2 neighbor is no longer present.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:39    192.168.10.6    Serial0/1
R1#
```

The **debug ip ospf events** command can be used to help troubleshoot mismatched parameters.

```
R1#debug ip ospf events
OSPF events debugging is on
R1#
06:37:25: OSPF: Rcv hello from 10.2.2.2 area 0 from Serial0/0 192.168.10.2
06:37:25: OSPF: Mismatched hello parameters from 192.168.10.2
06:37:25: OSPF: Dead R 40 C 20, Hello R 10 C 5
R1#undebug all
```

The output from this debug command states that the Dead timer received "**R**" from 10.2.2.2 is 40 seconds, and is configured "**C**" on this router for 20 seconds. The Hello timer received "**R**" from 10.2.2.2 is 10 seconds, and is configured "**C**" on this router for 5 seconds.

Issue the command **show ip ospf interface serial 0/0** and examine the new timer values. The timer values on R2, Router ID 10.2.2.2, is still Hello equals 10 seconds and Dead equals 40 seconds.

```
R1#show ip ospf interface serial 0/0
Serial0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 5, Dead 20, Wait 20, Retransmit 5
    Hello due in 00:00:02
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
R1#
```

Modify the Hello and Dead timer on R2's serial 0/0 interface to match that of R1's adjacent serial 0/0 interface.

```
      R2(config)#interface serial 0/0
      R2(config-if)#ip ospf hello-interval 5
      R2(config-if)#ip ospf dead-interval 20
```

```
06:29:06: %OSPF-5-ADJCHG: Process 1, Nbr 10.1.1.1 on Serial0/0 from LOADING to
FULL, Loading Done
```

Verify that the neighbors R1 and R2 are now adjacent.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:39    192.168.10.6    Serial0/1
10.2.2.2          1   FULL/  -        00:00:15    192.168.10.2    Serial0/0
R1#
```

Question 6: Do the Hello and Dead timers need to be the same on all interfaces on the router?

No, each interface needs only need to match the values of the adjacent neighbor.

4. Configuring OSPF Authentication

Whether intentional, or by accident, no unauthorized routers are to be exchanging updates within OSPF routing domain. An unauthorized router could announce a default route within OSPF and thereby funnel all traffic that should be forwarded to our ISP, instead gets forwarded to this rogue router.

We can help insure that this does not happen by adding encrypted authentication to each OSPF packet header using Message Digest (MD5) authentication. This mode of authentication sends a message digest, or hash, in place of the password. OSPF neighbors must be configured with the same message digest key number, encryption type, and password in order to authenticate using the hash.

To configure a message digest password for R1 to use on its serial 0/0 interface, use these commands:

```
R1(config)#interface serial 0/0
R1(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret
R1(config)#interface serial 0/1
R1(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret
R1(config)#interface fa 0/0
R1(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret

R1(config-if)#router ospf 1
R1(config-router)#area 0 authentication message-digest
```

Note: You may get the following message when configuring authentication on the interface. This message can be ignored.

```
OSPF: Invalid encrypted password: itsasecret
```

After entering these commands, wait 20 seconds, and then issue the **show ip ospf neighbor** command on R1.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:31    192.168.10.6    Serial0/1
R1#
```

Use the **debug ip ospf events** command to determine whyR1 does not see its neighbor R2, Router ID 10.2.2.2.

```
R1#debug ip ospf events
OSPF events debugging is on
R1#
07:08:50: OSPF: Send with youngest Key 1
07:08:50: OSPF: Rcv pkt from 192.168.10.6, Serial0/1 : Mismatch Authentication
type. Input packet specified type 0, we use type 2
07:08:52: OSPF: Rcv pkt from 192.168.10.2, Serial0/0 : Mismatch Authentication
type. Input packet specified type 0, we use type 2
```

Configure the same message digest password for R2 on its interfaces.

```
R2(config)#interface serial 0/0
R2(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret
R2(config)#interface serial 0/1
R2(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret
R1(config)#interface fa 0/0
R1(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret

R2(config-if)#router ospf 1
R2(config-router)#area 0 authentication message-digest
```

Configure the same message digest password for R3 on its interfaces.

```
R3(config)#interface serial 0/0
R3(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret
R3(config)#interface serial 0/1
R3(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret
R1(config)#interface fa 0/0
R1(config-if)#ip ospf message-digest-key 1 md5 7 itsasecret

R3(config-if)#router ospf 1
R3(config-router)#area 0 authentication message-digest
```

Verify adjacency using the **show ip ospf neighbor** command. Repeat this command for routers R2 and R3. All three routers should be adjacent once again.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:38    192.168.10.6    Serial0/1
10.2.2.2          1   FULL/  -        00:00:18    192.168.10.2    Serial0/0
R1#
```

5. Configuring Bandwidth and Examining the Routing Table

RFC 2328, OSPF version 2, J. Moy

> "A cost is associated with the output side of each router interface. This cost is configurable by the system administrator. The lower the cost, the more likely the interface is to be used to forward data traffic."
>
> RFC 2328 does not specify what values should be used for the cost. Cisco uses bandwidth.

Cisco uses a default cost of 10^8/bandwidth. 10^8 (100,000,000) is the reference bandwidth. The reference bandwidth is used so that the faster links (higher bandwidth) have lower costs. Remember, in routing metrics, lower the cost the better the route (i.e. with RIP 3 hops is better than 10 hops).

Note: The reference bandwidth can be modified to accommodate networks with links faster than 100,000,000 bps (100 Mbps) using the **`ospf auto-cost reference-bandwidth`** command.

Cost of a route is the cumulative costs of the outgoing interfaces from this router to the network.

On Cisco routers the bandwidth metric on all serial interfaces defaults to T1 (1.544 Mbps). The bandwidth value does not actually affect the speed of the link, but is used by OSPF and other routing protocols for its routing metric. It is important that the bandwidth metric reflects the actual speed of the link so that the routing table has accurate best path information.

By default all serial links have the same T1 bandwidth value of 1544 kbps. This means that the router has routing information that does not accurately reflect the network topology. For example, router R1 believes it has two equal-cost paths to the 192.168.8.0/30 network. It believes that both of its serial interfaces are connected to T1 links, although one of the links is a 64 kbps link and the other one is a 256 kbps link.

The bandwidth value can be verified by using the **`show interface`** command.

```
R1#show interface s 0/0
Serial0/0 is up, line protocol is up
  Hardware is PowerQUICC Serial
  Internet address is 192.168.10.1/30
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
  <text omitted>

R1#show interface s 0/1
Serial0/1 is up, line protocol is up
  Hardware is PowerQUICC Serial
  Internet address is 192.168.10.5/30
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
  <text omitted>
```

Because the bandwidth value is used in the OSPF routing metric, the routing table shows that the two paths are equal, even though they are not.

```
R1#show ip route  (before the bandwidth commands)
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       <text omitted>

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0
C       192.168.10.4 is directly connected, Serial0/1
O       192.168.10.8 [110/128] via 192.168.10.2, 00:11:32, Serial0/0
                     [110/128] via 192.168.10.6, 00:11:32, Serial0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/74] via 192.168.10.6, 00:11:33, Serial0/1
C       172.16.1.16/28 is directly connected, FastEthernet0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O       10.10.10.0/24 [110/74] via 192.168.10.2, 00:11:34, Serial0/0
C       10.1.1.1/32 is directly connected, Loopback0
R1#
```

Using the bandwidth command

When the serial interface is not T1 (1.544 Mbps), the interface requires manual modification with either the **bandwidth** or the **ip ospf cost** interface command. Both sides of the link should have the same value.

```
R1(config)#interface serial 0/0
R1(config-if)#bandwidth 64
R1(config-if)#exit
R1(config)#interface serial 0/1
R1(config-if)#bandwidth 256

R2(config)#interface serial 0/0
R2(config-if)#bandwidth 64
R2(config-if)#exit
R2(config)#interface serial 0/1
R2(config-if)#bandwidth 128

R3(config)#interface serial 0/0
R3(config-if)#bandwidth 256
R3(config-if)#exit
R3(config)#interface serial 0/1
R3(config-if)#bandwidth 128
```

After the bandwidth was modified on the serial interfaces to reflect the actual bandwidth of the links, router R1 now had only one route with the better of the two metrics. The better path to 192.168.10.8/30 network is through the serial 0/1 interface with the faster 256 kbps link compared to the serial 0/0 link at 64 kbps.

```
R1#show ip route  (after the bandwidth commands)
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       <text omitted>

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 3 subnets
C       192.168.10.0 is directly connected, Serial0/0
C       192.168.10.4 is directly connected, Serial0/1
O       192.168.10.8 [110/1171] via 192.168.10.6, 00:05:54, Serial0/1
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O       172.16.1.32/29 [110/400] via 192.168.10.6, 00:05:54, Serial0/1
C       172.16.1.16/28 is directly connected, FastEthernet0/0
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O       10.10.10.0/24 [110/1181] via 192.168.10.6, 00:05:55, Serial0/1
C       10.1.1.1/32 is directly connected, Loopback0
R1#
```

Using the `ip ospf cost` command

```
R1(config)#interface serial 0/0
R1(config-if)#bandwidth 64
```

Configuring the bandwidth to 64 kbps, sets the cost of that link to 10^8/bandwidth, or 10^8/64,000, or **1,562**.

An alternative method to using the **bandwidth** command is o use the **ip ospf cost** command. This command can be useful in multivendor environments when the non-Cisco routers use a metric other than bandwidth. This command can also be used instead of the bandwidth command, but specifying the cost of that interface. Here are examples for R1.

bandwidth Commands	**ip ospf cost Commands**
R1(config)#**interface serial 0/0** R1(config-if)#**bandwidth 64**	R1(config)#**interface serial 0/0** R1(config-if)#**ip ospf cost 1562**
R1(config)#**interface serial 0/1** R1(config-if)#**bandwidth 256**	R1(config)#**interface serial 0/1** R1(config-if)# **ip ospf cost 390**

The cost of each interface can be verified using the **show ip ospf interface** command.

```
R1#show ip ospf interface s 0/0
Serial0/0 is up, line protocol is up (looped)
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 1562

R1#show ip ospf interface s 0/1
Serial0/1 is up, line protocol is up
  Internet Address 192.168.10.5/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 390
  <text omitted>
```

The bandwidth value used by routing metrics can be verified using the **show interface** command.

```
R1#show interface s 0/0
Serial0/0 is up, line protocol is up (looped)
  Hardware is PowerQUICC Serial
  Internet address is 192.168.10.1/30
  MTU 1500 bytes, BW 64 Kbit, DLY 20000 usec,

R1#show interface s 0/1
Serial0/1 is up, line protocol is up
  Hardware is PowerQUICC Serial
  Internet address is 192.168.10.5/30
  MTU 1500 bytes, BW 256 Kbit, DLY 20000 usec,
```

Question 7: What would be the similar **ip ospf cost** commands for routers R2 and R3?

bandwidth Commands

Router R2

```
R2(config)#interface serial 0/0
R2(config-if)#bandwidth 64

R2(config)#interface serial 0/1
R2(config-if)#bandwidth 128
```

Router R3

```
R3(config)#interface serial 0/0
R3(config-if)#bandwidth 256

R3(config)#interface serial 0/1
R3(config-if)#bandwidth 128
```

ip ospf cost Commands

Router R2

```
R2(config)#interface serial 0/0
R2(config-if)#_ip ospf cost 1562_____

R2(config)#interface serial 0/1
R2(config-if)#_ip ospf cost 781______
```

Router R3

```
R3(config)#interface serial 0/0
R3(config-if)#___ip ospf cost 390___

R3(config)#interface serial 0/1
R3(config-if)# __ip ospf cost 781____
```

Calculating the OSPF routing metric

Cost of a route is the cumulative costs of the outgoing interfaces from this router to the network. Cisco uses a default cost of 10^8/bandwidth for each of its interfaces. Router R1's routing table shows a cost of 1181 to reach the 10.10.10.0/24 network via OSPF

```
R1#show ip route  (after the bandwidth commands)
       <text omitted>
O       10.10.10.0/24 [110/1181] via 192.168.10.6, 00:05:55, Serial0/1
```

The OSPF metric of 1181 was derived from the cumulative costs of the outgoing interfaces from this router to the network. Router R1 reaches the 10.10.10.0/24 network through R1's serial 0/1 interface, R3's serial 0/1 interface, and R2's FastEthernet 0/0 interface.

Performing the calculation from R1 to 10.10.10.0/24

The best path for packets from router R1 destined for 10.10.10.0/24 network is via router R3. There are three interfaces involved in this path:

1. R1: Serial 0/1
2. R3: Serial 0/1
3. R2: FastEthernet 0/0

We can view the bandwidth value for each outgoing interface using the **show interface** command. Remember, this value is only used in routing metrics for some routing protocols like OSPF and EIGRP and does not actually modify the speed of the link. However, in most cases it should reflect the actual speed of the link.

Here is the first outgoing interface on router R1:

```
R1#show interface s 0/1
Serial0/1 is up, line protocol is up
  Hardware is PowerQUICC Serial
  Internet address is 192.168.10.5/30
  MTU 1500 bytes, BW 256 Kbit, DLY 20000 usec,


R3#show inter s 0/1
Serial0/1 is administratively down, line protocol is down
  Hardware is PowerQUICC Serial
  MTU 1500 bytes, BW 128 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
```

Here is the third outgoing interface in router R2:

```
R2#show interface fa 0/0
FastEthernet0/0 is administratively down, line protocol is down
  Hardware is AmdFE, address is 000c.3010.9280 (bia 000c.3010.9280)
  MTU 1500 bytes, BW 10000 Kbit, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
```

Note: This lab was designed using routers with FastEthernet interfaces connected to 10 Mbps Ethernet switches. As a result of the autonegotiation between the router's FastEthernet interface and the 10 Mbps switch port, the router's interface is operating at 10 Mbps. This needs to be taken into account for any routing protocols, such as EIGRP and OSPF that use bandwidth as all or part of the routing metric. The cost associated with this interface will be that of 10 Mbps Ethernet and not 100 Mbps Fast Ethernet.

Again, Cisco uses a the cumulative cost of 10^8/bandwidth of all of the outgoing interfaces from the router to the destination network.

R1 Serial 0/1 interface:

```
      = (100,000,000 / 256,000)
      = 390
```

R3 Serial 0/1 interface:

```
      = (100,000,000 / 128,000)
      = 781
```

R2 FastEthernet 0/0 interface, operating at 10 Mpbs

```
      = (100,000,000 / 10,000,000
       = 10
```

Adding up the interface costs:

```
      390
      781
     + 10
      ---
     1181
```

Using show ip ospf interface command to determine OSPF costs

We can also determine the cost by examining using the **`show ip ospf interface`** command::

```
R1#show ip ospf interface serial 0/1
Serial0/1 is up, line protocol is up
  Internet Address 192.168.10.5/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 390
  <text omitted>

R3#show ip ospf interface serial 0/1
Serial0/1 is up, line protocol is up
  Internet Address 192.168.10.10/30, Area 0
  Process ID 1, Router ID 10.3.3.3, Network Type POINT_TO_POINT, Cost: 781
  <text omitted>

R2#show ip ospf interface fastethernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.10.10.1/24, Area 0
  Process ID 1, Router ID 10.2.2.2, Network Type BROADCAST, Cost: 10
  <text omitted>
```

Adding up the interface costs:

```
      390
      781
     + 10
      ---
     1181
```

Although the packet to 10.10.10.0/24 network must be routed by routers R2 and R3, this is faster, a better metric than sending it directly to R3 over the slower 64 kbps link. We can see this by calculating what the cost would be using the 64 kbps serial 0/0 interface on R1. The cost would be 1572 which is higher than the 1181.

```
R1#show ip ospf interface serial 0/0
Serial0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 1562
  <text omitted>

R2#show ip ospf interface fastethernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.10.10.1/24, Area 0
  Process ID 1, Router ID 10.2.2.2, Network Type BROADCAST, Cost: 10
  <text omitted>
```

Adding up the interface costs:

```
     1562
    +  10
     ----
     1572
```

6. Configuring a Default Route

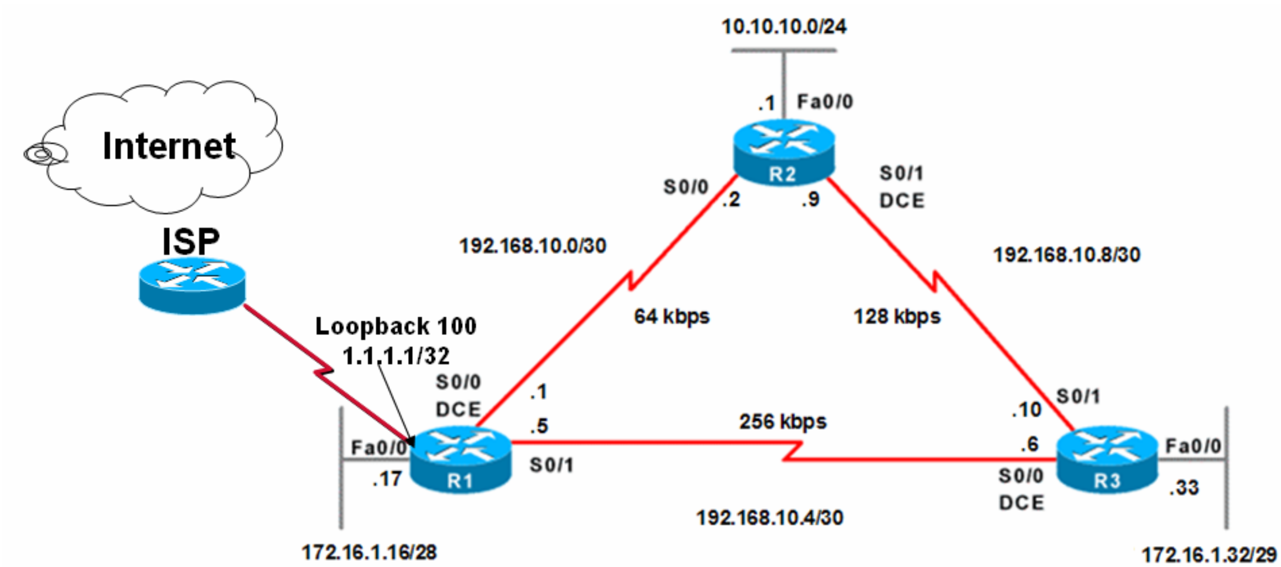
```
Router(config)#ip route 0.0.0.0 0.0.0.0 [ip address | interface]

Router(config)#router ospf 1
Router(config-router)#default-information originate [always]
```

Typically the router which is connected to the ISP propagates a default route to other routers in the OSPF routing domain. This is sometimes called the “Entrance” or “Gateway” router. In OSPF this router is known as the **ASBR** (Autonomous System Boundary Router).

If the ASBR has a default route configured (ip route 0.0.0.0 0.0.0.0), the **`default-information originate`** command is necessary to advertise 0.0.0.0/0 to the other routers in the area. If the **`default-information originate`** command is not used, the default “quad-zero” route will not be propagated. The **`always`** option will propagate a default “quad-zero” route even if one is not configured on this router.

The default route and the default-information originate command are usually only configured on the “Entrance” or “Gateway” router, the router that connects your network to the outside world.



In our example, if we will use R1 as our ASBR and loopback 100 interface with an IP address of 1.1.1.1/32 as our connection to the virtual ISP router.

```
R1(config)#interface loopback 100
R1(config-if)#ip add 1.1.1.1 255.255.255.255

R1(config)#ip route 0.0.0.0 0.0.0.0 loopback 100
```

By default, OSPF routers do not automatically propagate default routes. (Note: In CCNP 1, you will learn that in multi-area OSPF, there are certain areas such as stub areas, that will automatically propagate a default route.) To have an OSPF router propagate the default route, use the **default-information originate** command.

```
R1(config)#router ospf 1
R1(config-router)#default-information originate
```

Examine the routing tables on each router.

```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       <text omitted>

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

       <text omitted>
C       10.1.1.1/32 is directly connected, Loopback0
S*   0.0.0.0/0 is directly connected, Loopback100
R1#
```

```
R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       <text omitted>

Gateway of last resort is 192.168.10.10 to network 0.0.0.0

       <text omitted>
O*E2 0.0.0.0/0 [110/1] via 192.168.10.10, 00:02:31, Serial0/1
R2#
```

```
R3#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       <text omitted>

Gateway of last resort is 192.168.10.5 to network 0.0.0.0

       <text omitted>
O*E2 0.0.0.0/0 [110/1] via 192.168.10.5, 00:03:42, Serial0/0
R3#
```

Note: (*This information is discussed in CCNP 1.)* The "E2" means that this route is an External Type "2" OSPF route. External routes fall in one of two categories, External Type 1 or External Type 2. The difference between the two is in the way the cost (metric) of the route is being calculated at each router. An External Type 1 (E1) route includes the original external cost of the route plus the cost of each outgoing interface. This is identical to normal OSPF internal routes. However, the cost of an External Type 2 (E2) route is always the external cost, irrespective of the interior cost to reach that route. Since the default route has an external cost of 1 on the R1 router, that same cost is the same on all other OSPF routers no matter where that router is in the OSPF routing domain. Type 2 (E2) is the default!

Final Router Configurations

Router R1

```
version 12.2
!
hostname R1
!
no ip domain-lookup
!
interface Loopback0
 ip address 10.1.1.1 255.255.255.255
!
interface Loopback100
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 172.16.1.17 255.255.255.240
 ip ospf message-digest-key 1 md5 7 itsasecret
!
interface Serial0/0
 bandwidth 64
 ip address 192.168.10.1 255.255.255.252
 ip ospf message-digest-key 1 md5 7 itsasecret
 ip ospf hello-interval 5
 clockrate 64000
!
interface Serial0/1
 bandwidth 256
 ip address 192.168.10.5 255.255.255.252
 ip ospf message-digest-key 1 md5 7 itsasecret
!
router ospf 1
 log-adjacency-changes
 area 0 authentication message-digest
 network 172.16.1.16 0.0.0.15 area 0
 network 192.168.10.0 0.0.0.3 area 0
 network 192.168.10.4 0.0.0.3 area 0
 default-information originate
!
ip route 0.0.0.0 0.0.0.0 Loopback100
!
line con 0
 exec-timeout 0 0
 logging synchronous
```

Router R2

```
version 12.2
!
hostname R2
!
no ip domain-lookup
!
interface Loopback0
 ip address 10.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 10.10.10.1 255.255.255.0
 ip ospf message-digest-key 1 md5 7 itsasecret
!
interface Serial0/0
 bandwidth 64
 ip address 192.168.10.2 255.255.255.252
 ip ospf message-digest-key 1 md5 7 itsasecret
 ip ospf hello-interval 5
!
interface Serial0/1
 bandwidth 128
 ip address 192.168.10.9 255.255.255.252
 ip ospf message-digest-key 1 md5 7 itsasecret
 clockrate 64000
!
router ospf 1
 log-adjacency-changes
 area 0 authentication message-digest
 network 10.10.10.0 0.0.0.255 area 0
 network 192.168.10.0 0.0.0.3 area 0
 network 192.168.10.8 0.0.0.3 area 0
!
line con 0
 exec-timeout 0 0
 logging synchronous
```

Router R3

```
version 12.2
!
hostname R3
!
no ip domain-lookup
!
interface Loopback0
 ip address 10.3.3.3 255.255.255.255
!
interface FastEthernet0/0
 ip address 172.16.1.33 255.255.255.248
 ip ospf message-digest-key 1 md5 7 itsasecret
!
interface Serial0/0
 bandwidth 256
 ip address 192.168.10.6 255.255.255.252
 ip ospf message-digest-key 1 md5 7 itsasecret
 clockrate 64000
!
interface Serial0/1
 bandwidth 128
 ip address 192.168.10.10 255.255.255.252
 ip ospf message-digest-key 1 md5 7 itsasecret
!
router ospf 1
 log-adjacency-changes
 area 0 authentication message-digest
 network 172.16.1.32 0.0.0.7 area 0
 network 192.168.10.4 0.0.0.3 area 0
 network 192.168.10.8 0.0.0.3 area 0
!
line con 0
 exec-timeout 0 0
 logging synchronous
```